

A note on $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$

Xiang Liu,^{1,*} Chong Chen,¹ Wei-Zhen Deng,¹ and Xiao-Lin Chen^{1,†}

¹*Department of Physics, Peking University, Beijing 100871, China*

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Babar Collaboration announced two new excited charmed baryons $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$. We study their strong decays assuming they are D-wave states. Some assignments are excluded by comparing our numerical results with the experimental values of the total widths of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$. We also suggest some possible decay modes, which will be helpful to determine the properties of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$.

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At the recent 2007 Euro-physics Conference on High Energy Physics, Babar Collaboration reported the preliminary results about the observations of two new excited charmed baryons $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$ in the mass distribution of $\Lambda_c^+ K^- \pi^+$ [1]. Besides these new observations, Babar also confirmed the observation of $\Xi_c(2980)^+$ and $\Xi_c(3077)^+$ [2, 3]. The masses and widths of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$ are

$$\begin{aligned} m_{\Xi_c(3055)^+} &= 3054.2 \pm 1.2 \pm 0.5 \text{ MeV}/c^2, \\ \Gamma_{\Xi_c(3055)^+} &= 17 \pm 6 \pm 11 \text{ MeV}/c^2, \\ m_{\Xi_c(3123)^+} &= 3122.9 \pm 1.3 \pm 0.3 \text{ MeV}/c^2, \\ \Gamma_{\Xi_c(3123)^+} &= 4.4 \pm 3.4 \pm 1.7 \text{ MeV}/c^2. \end{aligned}$$

In order to understand the recently observed $\Lambda_c(2880, 2940)^+$, $\Xi_c(2980, 3077)^{+,0}$, and $\Omega_c(2768)^0$ [2, 3, 4, 5, 6], we studied the strong decays of the S-wave, P-wave, D-wave, and radially excited charmed baryons using the 3P_0 model systemically [7]. (For more details of the 3P_0 model, see Ref. [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]).

In this short note, we analyze the strong decays of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$ using the same formalism as in Ref. [7], which will be helpful to determine the quantum number of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$. Because the parity of these states is even, they are either the first radial excitation or D-wave charmed baryons. In our previous work [7], we studied the total decay width of $\Xi_c(3077)^+$ assuming it's a candidate of the first radial excitation. Because their masses are close, the decay pattern of $\Xi_c(3055, 3123)^+$ should be similar to that presented in Ref. [7] if either of them is the radial excitation. In this work, we will not discuss the assignment for $\Xi_c(3055, 3123)^+$ (Interested reader can consult Ref. [7]). In the following, we estimate their strong decays if $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$ are candidates of D-wave

states. We list the spectrum of D-wave excited spectrum in Fig. 1. We omit the detailed expressions of the strong decays of D-wave charmed baryons derived by this model. Interested readers may consult our former paper [7] for details.

The decay widths of charmed baryons from the 3P_0 model involve several parameters: the strength of quark pair creation from vacuum γ , the R value in the harmonic oscillator wave function of meson and the $\alpha_{\rho,\lambda}$ in the baryon wave functions. We follow the convention of Ref. [20] and take $\gamma = 13.4$, which is considered as a universal parameter in the 3P_0 model. The R value of π and K mesons is 2.1 GeV^{-1} [20] while it's $R = 2.3 \text{ GeV}^{-1}$ for the D meson [21]. $\alpha_\rho = \alpha_\lambda = 0.5 \text{ GeV}$ for the proton and Λ [19]. For S-wave charmed baryons, the parameters α_ρ and α_λ in the harmonic oscillator wave functions can be fixed to reproduce the mass splitting through the contact term in the potential model [22]. Their values are $\alpha_\rho = 0.6 \text{ GeV}$ and $\alpha_\lambda = 0.6 \text{ GeV}$. For P-wave and D-wave charmed baryons, α_ρ and α_λ are expected to lie in the range $0.5 \sim 0.7 \text{ GeV}$. In the following, our numerical results are obtained with the typical values $\alpha_\rho = \alpha_\lambda = 0.6 \text{ GeV}$. In the following, we listed the numerical results of the strong decays of $\Xi_c(3055)^+$ and $\Xi_c(3123)^+$ in Table I-II.

At present only total widths of $\Xi_c(3055, 3123)^+$ are measured experimentally. Through comparing our numerical results with experimental values, we exclude some D-wave assignments for $\Xi_c(3055, 3123)^+$, which are marked by "x" in Table I-II. In order to fully determine the quantum numbers of $\Xi_c(3055, 3123)^+$, we suggest:

- Search for other possible decay modes of $\Xi_c(3055, 3123)^+$. From Table I-II, one notes that some decay modes are forbidden for $\Xi_c(3055, 3123)^+$ with several assignments of their quantum numbers, which provides some useful hint for exclusion or confirmation of certain J^P .

- Measure the ratio between different decay modes $\Xi_c^0 \pi^+ : \Xi_c'(0) \pi^+ : \Xi_c^{*0} \pi^+ : \Sigma_c^{++} K^- : \Sigma_c^{*++} K^- : \Lambda_c^+ K^0 : D^+ \Lambda$. Our numerical results show this ratio is different for the different assignment.

*Electronic address: xiangliu@pku.edu.cn

†Electronic address: xlchen@th.phy.pku.edu.cn

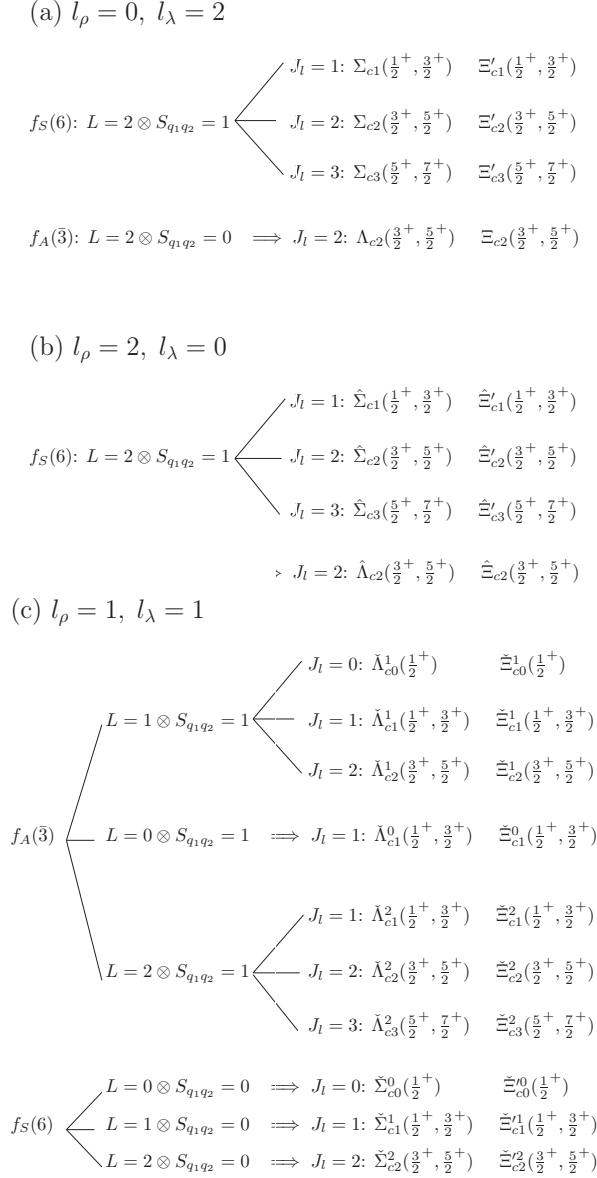


FIG. 1: The notations for the D-wave charmed baryons.

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TABLE I: The decay widths of $\Xi_c^+(3055)$ with different D-wave assignments. Here we list the results with the typical values $\alpha_\rho = 0.6$ GeV and $\alpha_\lambda = 0.6$ GeV.

Assignment	$\Xi_c^0 \pi^+$	$\Xi_c'^0 \pi^+$	$\Xi_c^{*0} \pi^+$	$\Sigma_c^{++} k^-$	$\Sigma_c^{*++} k^-$	$\Lambda_c^+ k^0$	$D^+ \Lambda$	Remark
$\Xi_{c2}(\frac{3}{2}^+)$	0.0	1.9	0.25	2.2	0.12	0.0	0.0	
$\Xi_{c2}(\frac{5}{2}^+)$	0.0	0.028	1.4	0.83×10^{-2}	0.69	0.0	0.0	
$\Xi_{c1}'(\frac{1}{2}^+)$	6.4	1.3	0.38	1.5	0.19	8.0	2.4	
$\Xi_{c1}'(\frac{3}{2}^+)$	6.4	0.32	0.96	0.37	0.48	8.0	2.4	
$\Xi_{c2}'(\frac{3}{2}^+)$	0.0	2.9	0.36	3.3	0.17	0.0	0.0	
$\Xi_{c2}'(\frac{5}{2}^+)$	0.0	0.019	2.1	0.55×10^{-2}	1.0	0.0	0.0	
$\Xi_{c3}'(\frac{5}{2}^+)$	0.15	0.022	0.78×10^{-2}	0.63×10^{-2}	0.30×10^{-3}	0.18	0.0067	×
$\Xi_{c3}'(\frac{7}{2}^+)$	0.15	0.012	0.011	0.35×10^{-2}	0.41×10^{-3}	0.18	0.0067	×
$\Xi_{c2}^*(\frac{3}{2}^+)$	0.0	27.4	21.3	14.4	2.5	0.0	0.0	×
$\Xi_{c2}^*(\frac{5}{2}^+)$	0.0	27.4	21.3	14.4	2.5	0.0	0.0	×
$\Xi_{c1}^*(\frac{1}{2}^+)$	163	18.3	3.5	9.6	0.41	205	15.5	×
$\Xi_{c1}^*(\frac{3}{2}^+)$	163	4.6	8.9	2.4	1.0	205	15.5	×
$\Xi_{c2}^*(\frac{3}{2}^+)$	0.0	41.1	15.9	21.5	1.9	0.0	0.0	×
$\Xi_{c2}^*(\frac{5}{2}^+)$	0.0	18.3	24.8	9.6	2.9	0.0	0.0	×
$\Xi_{c3}^*(\frac{5}{2}^+)$	105	20.9	10.1	10.9	1.2	131	10.0	×
$\Xi_{c3}^*(\frac{7}{2}^+)$	105	11.7	13.7	6.1	1.6	131	10.0	×
$\Xi_{c0}^0(\frac{1}{2}^+)$	0.0	0.23	0.46	1.9	2.9	0.0	0.0	
$\Xi_{c1}^0(\frac{1}{2}^+)$	9.8	0.30	0.15	2.6	0.95	12.4	0.60	
$\Xi_{c1}^0(\frac{3}{2}^+)$	9.8	0.075	0.38	0.65	2.4	12.4	0.60	
$\Xi_{c1}^1(\frac{1}{2}^+)$	0.0	34.7	9.8	36.0	4.1	0.0	0.0	×
$\Xi_{c1}^1(\frac{3}{2}^+)$	0.0	8.7	24.4	9.0	10.3	0.0	0.0	×
$\Xi_{c0}^1(\frac{1}{2}^+)$	0.0	34.7	39.1	36.0	16.6	0.0	0.0	×
$\Xi_{c1}^1(\frac{3}{2}^+)$	97.6	17.4	4.9	18.0	2.1	122	28.2	×
$\Xi_{c1}^1(\frac{5}{2}^+)$	97.6	4.3	12.2	4.5	5.2	122	28.2	×
$\Xi_{c2}^1(\frac{3}{2}^+)$	0.0	21.7	2.4	22.5	1.0	0.0	0.0	×
$\Xi_{c2}^1(\frac{5}{2}^+)$	0.0	0.0	14.7	0.0	6.2	0.0	0.0	
$\Xi_{c2}^2(\frac{3}{2}^+)$	0.0	8.6	4.7	12.3	1.5	0.0	0.0	
$\Xi_{c2}^2(\frac{5}{2}^+)$	0.0	4.7	8.7	2.8	4.4	0.0	0.0	
$\Xi_{c1}^2(\frac{1}{2}^+)$	21.9	5.7	2.0	8.2	1.1	27.2	12.2	×
$\Xi_{c1}^2(\frac{3}{2}^+)$	21.9	1.4	4.9	2.1	2.8	27.2	12.2	×
$\Xi_{c2}^2(\frac{3}{2}^+)$	0.0	12.9	4.1	18.5	1.5	0.0	0.0	×
$\Xi_{c2}^2(\frac{5}{2}^+)$	0.0	3.2	11.7	1.9	6.3	0.0	0.0	
$\Xi_{c3}^2(\frac{5}{2}^+)$	17.4	3.6	1.9	2.2	0.41	21.9	2.1	×
$\Xi_{c3}^2(\frac{7}{2}^+)$	17.4	2.0	2.5	1.2	0.57	21.9	2.1	×

TABLE II: The decay widths of $\Xi_c^+(3123)$ with different D-wave assignments. Here we list the results with the typical values $\alpha_\rho = 0.6$ GeV and $\alpha_\lambda = 0.6$ GeV.

Assignment	$\Xi_c^0 \pi^+$	$\Xi_c^{*0} \pi^+$	$\Xi_c^{*0} \pi^+$	$\Sigma_c^{++} k^-$	$\Sigma_c^{*++} k^-$	$\Lambda_c^+ k^0$	$D^+ \Lambda$	Remark
$\Xi_{c2}(\frac{3}{2}^+)$	0.0	2.8	0.43	4.5	0.49	0.0	0.0	
$\Xi_{c2}(\frac{5}{2}^+)$	0.0	0.075	2.3	0.053	2.8	0.0	0.0	
$\Xi_{c1}(\frac{1}{2}^+)$	8.3	1.9	0.63	3.0	0.79	10.2	5.5	×
$\Xi_{c1}(\frac{3}{2}^+)$	8.3	0.46	1.6	0.76	2.0	10.2	5.5	×
$\Xi_{c2}(\frac{3}{2}^+)$	0.0	4.2	0.60	6.8	0.72	0.0	0.0	
$\Xi_{c2}(\frac{5}{2}^+)$	0.0	0.050	3.4	0.035	4.3	0.0	0.0	
$\Xi_{c3}(\frac{5}{2}^+)$	0.32	0.057	0.026	0.040	0.010	0.44	0.069	×
$\Xi_{c3}(\frac{7}{2}^+)$	0.32	0.032	0.035	0.023	0.013	0.44	0.069	×
$\Xi_{c2}(\frac{3}{2}^+)$	0.0	58.9	53.0	56.0	30.0	0.0	0.0	×
$\Xi_{c2}(\frac{5}{2}^+)$	0.0	58.9	53.0	56.0	30.0	0.0	0.0	×
$\Xi_{c1}(\frac{1}{2}^+)$	311	39.2	8.8	37.4	5.0	411	85.9	×
$\Xi_{c1}(\frac{3}{2}^+)$	311	9.8	22.1	9.3	12.5	411	85.9	×
$\Xi_{c2}(\frac{3}{2}^+)$	0.0	88.3	40.0	84.1	22.5	0.0	0.0	×
$\Xi_{c2}(\frac{5}{2}^+)$	0.0	39.2	61.8	37.4	35.0	0.0	0.0	×
$\Xi_{c3}(\frac{5}{2}^+)$	200	44.8	25.2	42.7	14.3	264	55.3	×
$\Xi_{c3}(\frac{7}{2}^+)$	200	25.2	34.0	24.0	19.3	264	55.3	×
$\Xi_{c0}^0(\frac{1}{2}^+)$	0.0	4.3	0.35	0.015	2.5	0.0	0.0	
$\Xi_{c1}^0(\frac{1}{2}^+)$	36.5	5.8	0.12	0.020	0.82	52.7	1.8	×
$\Xi_{c1}^0(\frac{3}{2}^+)$	36.5	1.4	0.29	0.005	2.0	52.7	1.8	×
$\Xi_{c1}^1(\frac{1}{2}^+)$	0.0	54.3	17.0	80.2	18.3	0.0	0.0	×
$\Xi_{c1}^1(\frac{3}{2}^+)$	0.0	13.6	42.6	20.1	45.8	0.0	0.0	×
$\Xi_{c0}^1(\frac{1}{2}^+)$	0.0	54.3	68.2	80.2	73.3	0.0	0.0	×
$\Xi_{c1}^1(\frac{1}{2}^+)$	139	27.1	8.5	40.1	9.2	175	73.3	×
$\Xi_{c1}^1(\frac{3}{2}^+)$	139	6.8	21.3	10.0	22.9	175	73.3	×
$\Xi_{c2}^1(\frac{3}{2}^+)$	0.0	33.9	4.3	50.1	4.6	0.0	0.0	×
$\Xi_{c2}^1(\frac{5}{2}^+)$	0.0	0.0	25.6	0.0	27.5	0.0	0.0	×
$\Xi_{c2}^2(\frac{3}{2}^+)$	0.0	10.5	10.0	21.3	8.1	0.0	0.0	×
$\Xi_{c2}^2(\frac{5}{2}^+)$	0.0	9.9	13.9	9.8	16.9	0.0	0.0	×
$\Xi_{c1}^2(\frac{1}{2}^+)$	21.6	7.0	2.8	14.2	4.0	25.2	21.1	×
$\Xi_{c1}^2(\frac{3}{2}^+)$	21.6	1.7	7.1	3.6	10.0	25.2	21.1	×
$\Xi_{c2}^2(\frac{3}{2}^+)$	0.0	15.7	8.1	32.0	7.4	0.0	0.0	×
$\Xi_{c2}^2(\frac{5}{2}^+)$	0.0	6.6	17.7	6.6	23.2	0.0	0.0	×
$\Xi_{c3}^2(\frac{5}{2}^+)$	32.7	7.5	4.4	7.5	3.0	43.1	10.1	×
$\Xi_{c3}^2(\frac{7}{2}^+)$	32.7	4.2	5.9	4.2	4.1	43.1	10.1	×